An auxanometer for the registration of growth of stems in thickness.

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WITH PLATES XII AND XIII.

Description of the instrument.

The main feature of this auxanometer for measuring growth in thickness (see plate XII) is a balanced glass arm supported near one end, acting as a multiplying lever. The longer part of the arm has a bristle fastened at the end that registers the lateral movement upon one or more blackened glass rods carried round on a brass spool, the spool being revolved by a clock.

The glass arm passes through a short brass tube held between two hardened steel points. The position of the arm is varied by changing the brass Y, holding the points, which is kept in place by a set screw. The longer arm is counterbalanced by a weight suspended from the shorter arm. Close behind the steel points is a small fork; this fork presses the stem to be measured upon one side, and the glass arm upon the other. The fork is made at the end of a screw thread, to admit of movement backward and forward, to accommodate large or small stems. To keep the long glass tube straight a fine wire is stretched from one end to the other, passing over a support, thus forming a truss. These pieces of mechanism are held in place by a long wooden beam, supported on three feet placed near one end, one of which is provided with a levelling screw to admit of adjustment for plants of varying height. The spool is made to revolve by having the axis extended at one end beyond its supports to carry a grooved pulley, which is connected with a similar grooved pulley, attached to the hour hand spindle of the clock, by means of a small rubber band. The friction between the rubber and the grooved pulleys, and the uniform tension, preclude slipping.

The instrument is used by placing the stem of the plant between the fixed fork and the short arm of the glass rod. Perfect contact of the glass arm and the stem of the plant is maintained by means of a very light wire spring fastened between the beam and the glass arm (not shown in the illustration).

The distance between the point of contact with the plant and the pivot is one-fortieth of the distance from the blackened glass rod to the pivot, so that any growth of the plant is magnified forty times on the blackened rod. Thus a growth of one-thousandth of an inch will be represented by one-twenty-fifth of an inch on the blackened rod.

From the blackened glass rod a permanent record can be obtained by making a print of it on sensitized paper, from which direct measurements can be made.

The instrument was devised and made by my brother, M. J. Golden, professor of practical mechanics in Purdue University.

The following observations are given to show the work done by the apparatus.

Record of experiments.

The study of growth in length has received a great deal of attention from many physiologists, notably Sachs. He has found that there is a maximum and a minimum point of growth, and also that there are forms of growth for which no reason, as yet, has been assigned, these latter being termed "spontaneous variations." Growth in length has been studied for small as well as large plants, but in no recorded case has growth in thickness been studied upon any but large plants, and in these the measurements were made by the observer at intervals of time with some calipering instrument, thus introducing a possible error due to the personal equation. The periodicity of growth has been determined for growth in length, but has been assumed for growth in thickness, largely as a result of measurements of growth in length and as an accompaniment to it.

The amount of tension is one of the principal factors in growth, as there is little growth when the tension is low, and greatest growth when the tension is high. Kraus[1] has found in his measurements on stems of trees that there is a maximum and a minimum point of tension, these occurring at about the same time that the maximum and minimum points of growth have been found to occur by other investigators. But he states that he has found that temperature has very little effect on tension for the ordinary variations occur between 10–30°C. In his experiments on the tension of stems his

[1] Kraus, G., Die tägliche Schwellungsperiode der Pflanzen 28.

figures show the greatest tension when the temperature was the lowest at 2 A. M., while the tension is lowest at 1 P. M. when the temperature was 2° short of the highest point it had attained in two days.

Millardet[2] has verified the statements of Kraus with respect to the periodicity of tensions, working with *Mimosa pudica*, but he has found that a rise of temperature increases the tension, while a fall of temperature diminishes it. Kraus' measurements were made upon stems of trees (maple, birch, and oak) that would not show the effect of temperature readily, while Millardet's were made upon the stem, petiole, and leaf of a plant that would easily show small differences of tension. The subject of tension in tissues is very important as each separate tissue has its own rate of growth, causing tensions to be set up in the various tissues. In measuring stems one has to determine whether an increase in the thickness is temporary, and due only to tension, or a permanent increase due to growth. If it be tension only, a decrease in thickness will follow the increase, this being caused by a contraction of the tissues.

The plants used for the following work were tomatoes and potatoes, these being good growers in thickness as well as length, and having internodes smooth, or at least free from stiff hairs. This point had to be looked after carefully so as to allow of good adjustment of the instrument. While the measurements were being made, a registering thermometer was placed near the instrument. The work was done during December and January, 1892–3, and while there were but few sunny days, the plants were under favorable conditions for growth, as the transpiration from the plants would be low, and but slight retardation of growth from light could occur; the temperature also, for the most part, was as high as it would be in the warmer months, the work having been done in a steam-heated greenhouse.

The tomato was measured first, and on Dec. 28th and 29th the record of the second registration showed that the stem was less in diameter than for the first registration, but after that each registration showed the diameter to be greater than at first. In both cases of less diameter, the temperature was very low, which might have occasioned a low tension.

[2]Millardet, A., Nouvelles recherches sur la periodicité de la tension: étude sur les mouvements periodiques et paratoniques de la sensitive, 1870.

A factor of much importance in the growth in diameter is that of temperature, the plant responding within a short period to a rise in temperature by a more rapid growth, and a slower growth following a fall in temperature. The term growth is used, but it is, of course, understood that the increase in diameter includes the tension as well, as the results of the two are not separable.

Taking the line of growth for the tomato for Jan. 1st (plate XIII), it can be seen that the growth bears a close relation to the temperature, the high temperature being followed promptly by an increased growth. The total growth for the thirty hours can be seen very readily in the line plotted.

The same points are seen in the lines of growth constructed from the record of the potato for Jan. 6th (plate XIII). The potato gave a much greater growth, but aside from that the growth took place in the same manner as in the tomato. On these dates occurred the greatest growth obtained from either plant. These two have been selected as typical lines of growth for the two plants measured.

In the lines of growth obtained by taking the average amounts of growth for the different periods, the effect of temperature is not so apparent as there were no regular variations in the temperature, consequently the average line of temperature is not satisfactory in showing the relation between temperature and growth.

Examining the average line of growth for the tomato which was obtained from seven days' records, there are two points of maximum growth, one between 5 and 8 o'clock in the morning, the other between 2 and 5 o'clock in the evening. For the potato the maximum point came earlier in the morning, but was at about the same time in the evening. It was obtained from twelve days' records. The potato under approximately the same conditions gave much the more vigorous growth, but the records for both of them showed clearly that the increase in diameter was really growth, and not an expansion that would be followed by a contraction.

These observations and comparisons show what is possible by the use of the instrument. Further observations are being made in connection with an auxanometer registering growth in length, which was also devised by my brother, and is similar to the one exhibited by Dr. Arthur at the Madison meeting of the A. A. A. S.

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